

## 1.0 General Participation and Rules

### 1.1. Who is eligible to participate in the competition?

A: Anyone can participate in the competition as long as they are not a citizen or an entity from a country listed on the NASA Export Control Program List of designated countries under Category 2/Column 2. (The current list of designated countries can be found at [https://oiiir.hq.nasa.gov/nasaecp/docs/DCList\\_02-15-2017.pdf](https://oiiir.hq.nasa.gov/nasaecp/docs/DCList_02-15-2017.pdf))

### 1.2. What are the rules for teams to be eligible to win prizes?

A: To be eligible to win a prize, the Team must be ~~solely~~ mostly (50% or more) comprised of Team Members and Entity Members, as applicable, that are either:

- An individual that is a citizen or permanent resident of the United States; or
- An entity that is incorporated in and maintains a primary place of business in the United States.

### 1.3. Can a person with a green card (not US citizen) participate in the competition?

A: Yes, a person with a green card that is a permanent resident of the United States may participate in the competition.

### 1.4. Can you participate as an individual in the competition?

A: Anyone can participate in the competition as long as they are not a citizen or an entity from a country listed on the NASA Export Control Program List of designated countries under Category 2/Column 2. (The current list of designated countries can be found at [https://oiiir.hq.nasa.gov/nasaecp/docs/DCList\\_02-15-2017.pdf](https://oiiir.hq.nasa.gov/nasaecp/docs/DCList_02-15-2017.pdf))  
To be eligible to win prizes the individual must be either a citizen or permanent resident of the United States.

### 1.5. What happens if the participant is a minor (under 18 years old)?

A: If a participant is a minor, then the parent or legal guardian of the participant must sign the registration form.

### 1.6. Can we add additional team members after we have registered and completed the Team Registration form?

A: New team members may be added to the team after the initial registration period ends. Team members previously registered for the challenge on one team may not switch teams during the same phase of the competition.

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- 1.7. When are the various submissions due? Is there additional guidance for preparing the documents and submissions required by the rules?

A: The submission schedule is as follows (deadlines are all midnight, CST or CDT):

February 28, 2017 – Completed, signed team agreement as well as the proposal submission as described in section 8.2 of the rules. Deadline for team agreement is extended to March 7, 2017 due to late release of final, corrected version of team agreement form. Proposal is still due February 28, 2017.

March 31, 2017 – Level 1 submission shall include documentation and videos as specified in rules sections 4.3.5 and 5.4. An updated version of the documentation submitted February 28 to fulfill section 8.2 should also be included. Proof of insurance per 4.3.7 should also be submitted. The complete cone and cylinder samples must be received by Bradley University no later than April 14, 2017.

March 31 - \$1000 fee is due to Bradley University

March 1, April 1, May 1, June 1, July 1, August 1, September 1, 2017 – 10.3.3 Monthly total Team investments and/or expenditures along with a brief progress report shall be provided per 4.11.

May 31, 2017 – Level 2 submission shall include documentation and videos as specified in rules section 6.3. An updated version of the documentation submitted February 28 to fulfill section 8.2 and of the documentation submitted March 31 to fulfill 4.3.5 should also be included. The complete beam sample must be received by Bradley University no later than June 14, 2017.

July 31, 2017 – Level 3 submission should include a further revision of the documentation submitted earlier per section 4.3.5. Also, any changes to the documents after this date must be resubmitted ASAP.

Additional guidance and detail for preparing Level 1, 2, and 3 submissions will be sent directly to participating teams at least 30 days in advance of the deadline. Other ad hoc requests for information not listed here may be required to help the execution team plan for a successful competition.

- 1.7.1. If I have missed these deadlines, is there still an opportunity to join the completion and compete at the Level 3 event?

A: As documented in Rules section 6.5.3, teams may successfully complete and submit all level 1 and 2 requirements by 4 weeks prior to the August 21<sup>st</sup> level 3 competition and have the opportunity to be invited to the competition. If interested, please register on the Bradley web site immediately to start the process.

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- 1.8. What if I perceive a conflict between what was presented on a webinar and the rules or any other form of communication between the challenge administrators and the competing teams?

A: If you perceive a conflict please notify the challenge administrators. Mistakes can be made or statements can be taken out of context. Clarifications to the rules will be communicated to all teams to attain to the highest level of fairness and may even result in modification to the rules for clarity. The official rules in its latest version on the Bradley 3D-Printed Habitat Challenge web-site is the super-precedent and authority for the competition.

- 1.9. If a team at the Level 3 event is unable to print a dome that meets the minimum requirements, including the ability to support the minimum load, are they able to place in the competition and be considered for the prize money?

A: The goal of the Level 3 competition is to demonstrate the ability to autonomously print a dome structure that meets the spirit and rules of the competition. To determine if the dome has the structural integrity to be transported to the testing area, a load of approximately 50 kg will be applied to the top of the structure in the form of sandbags. Each team will be required to place the sandbags on top of their dome. If this test is not passed, the team will receive a zero score for the level 3 competition, regardless of the amount of points which would have been assigned to the team based on their cylinders and beams printed at the level 3 competition. Prize awards for successfully printed cylinders and beams have already been distributed and teams have been recognized in Level 1 and Level 2 respectively. Domes which pass this initial transportability test then will be subjected to increasing vertical compressive loads using Caterpillar test equipment until complete structural failure (i.e. total collapse) of the dome to determine the maximum load supported by the dome. The dome must support the minimum 625 kg vertical load for any points to be earned for the dome portion of the Level 3 competition. Should the dome not pass the 625 kg load test, competitors will be given Level 3 points based only on Level 3 cylinders and beams printed, toward a possible prize position and prize money. In the formula below, the Dome would be awarded zero points, and the Level 3 score would be calculated based on the C39 avg and C78 avg scores only.

$$\text{Level 3 Score} = DP_{factor} \times \left\{ \frac{C39_{avg}}{10} + C78_{avg} + (Dome \times 10) \right\}$$

Also, while international teams can place in the Level 3 competition if they meet the above requirements, they are not eligible for prize money (legally) and thus any prize money corresponding to the place of an international team will not be awarded and will be used for future competitions (similar to levels 1 and 2) as explained in FAQ 2.3)

## 2.0 International Participation

- 2.1. How can an international team compete given the requirement (4.1.2) that all teams must be physically located in the United States? What parts of the competition require international teams to be in the US?
- 2.2. Besides, the ineligibility for prizes, what else should international teams expect?

A: International teams can register and participate in Level 1, 2 and 3 Challenges. International teams are exempt from the requirements of 4.1.2 because they are not eligible for prizes. International teams need to physically attend the Level 3 competition but can participate in Levels 1 and 2 remotely (8.1.3). ASTM standards and specimen submission requirements remain the same for Level 1 and 2 remote participants. Customs and visa requirements pertaining to the Level 3 competition are the responsibility of the teams. Rules updates will clarify this as well.

- 2.3. If an international team(s) has a top 3 score. How is the prize money allocated?

A: If an international team wins first, second, or third, for Level 3 their prize money (which cannot be awarded by law) would be deducted from the Level 3 prize purse and used for future prizes. This was a precedent that was set in 3D-Printed Habitat Phase 1 Design Challenge when the 3<sup>rd</sup> Place winner was an international team and the prize money was not awarded. This 3<sup>rd</sup> place prize amount for Phase 1 was rolled to a future competition prize purse and not awarded in Phase 1.

Also, Phase 2 Level 2 prize money award will be done in much the same way as Level 1, but the rules state that the prize purse is "up to \$500k" for Level 2. The total prize purse can be less than \$500k according to the rules as written. For Level 2, for each team meeting the scoring criteria, there will be \$50k added to the prize purse for Level 2, limiting the amount that will be distributed. For example, if only 2 teams have qualifying scores, there will be a 2x\$50k prize purse for a total \$100k. If there are 10 or more teams with qualifying scores for prize money, \$500k will be the prize purse for distribution for Level 2. Another item to note is that if an international team qualifies for points and they are in the top 10, their prize money (which cannot be awarded by law) would be deducted from the level 2 prize purse and used for future prizes.

~~A: The prize money will be distributed to the 3 highest scoring US-based teams. Thus, it is possible that the "first prize" may not be awarded to the team that is in "first place" based on total points scored.~~

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2.4. When does the 4 international team limit apply? How are the 4 teams chosen if more than 4 register?

A: There is no limit to the number of international teams that can participate in Levels 1 and 2. The 4 team limit pertains to Level 3 only. All teams that meet the minimum success criteria for Levels 1 and 2 will be ranked from highest to lowest score. The 4 highest international scores will be retained and the remaining international scores will be removed from the list. Next, the list will be resorted from highest to lowest score. The top 30 teams will be eligible for Level 3.

## 3.0 Feedstocks

3.1. What feedstocks will be provided for the participants and how much will be allocated to each team.

3.2. What are the limitations on sizing and grading of feedstock?

A: Teams are required to procure their own feedstock for all 3 levels of the competition. Sizing and grading of the feedstock may be done ahead of the competition. Samples of feedstock may be collected by the competition organizers to verify composition.

3.3. How would a Martian simulant such as JSC-MARS-1A be scored on the material applicability scale.

A: Mars JSC-1A, is a CBI - Crushed basaltic igneous rock (SiO<sub>2</sub> weight percent less than or equal to 57), rates as 10 (Most Relevant) on material applicability sliding scale.

3.4. Is there a minimum quantity requirement for indigenous materials?

A: Yes, rule 4.6.5. requires a minimum criteria 70% indigenous materials, and failure to meet this minimum requirement will result in disqualification.

3.5. What if I would like to use an indigenous material that is not on the Table of materials?

A. Creative use of all indigenous materials is encouraged; please submit your proposed material and usage for the judges to evaluate if a scoring factor can be assigned.

3.6. Is it legal to process the feedstock material at any point? For example, can a specimen be baked after printing?

A: Feedstock processing or curing methods which can be completed safely, in real time, including at the level 3 event, can be pursued. At the level 3 event, we will have to shut down all printing and powered operations at the end of the working day. The teams will have about 8 total hours to get their printer prepped and the printing completed during a given printing day. ~~Keep in mind that at the level 3 event, 4 hours has been allotted as the printing time window, and all printing machine functions, including curing energy additions, must be stopped at the end of the printing time window.~~ Passive curing can continue overnight as long as any exothermic reactions do not require monitoring or active cooling to maintain safety.

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- 3.7. Is it legal to extract materials out of the feedstock and use them? For example, extracting magnesium out of dolomite.

A: If material extraction will be occurring outside of the printing machine and printing activity, it must be demonstrated to the judges and approved in advance of Level 1, 2 or 3 submissions which make use of extracted materials as feedstock. The process and energy required should be declared and suitable for scalable construction and it must be safe to implement. Finally, the actual printing activity must use material that was extracted using this method, not material from a different source.

For the Level 3 competition, it is recognized that the amount of feedstock required for three cylinders, three beams and a dome is not insignificant and it may not be practical to use solely extracted feedstocks as described above. Teams who wish to use equivalent materials can make a proposal for evaluation by the judges. Decisions will be based on the teams' demonstration of traceability to a process and tests showing the equivalency of material performance.

- 3.8. Are we allowed to use basalt fiber powder or only basalt rock powder?

A: Yes, it is allowed.

- 3.9. How will materials be scored if they are not listed in the rules?

A: Materials will be scored according to their origin and prevalence on Mars. For example, fly ash is a common additive in concrete. Fly ash is a byproduct of burning coal, and coal-burning will most likely not occur on Mars. Some geologic materials are similar in composition to fly ash; those products may be used and often will score very high as they are primarily basaltic. One major difference between the geologic and fly ash materials is grain size, which has implications for reactivity. Another example is slag. Slag is a byproduct of smelting and ore refining. This also would likely not occur on Mars (at least in the early days of settlement). However, slag can have a mineral-like composition. If this is the case, the composition of the slag would be compared to the types of minerals on Mars and scored accordingly. One more example is potassium silicate. Potassium silicate can be produced from potassium-rich minerals found primarily in sedimentary materials on Mars. Thus, potassium silicate would obtain a GSS rating.

- 3.10. Are there any limitations on processing indigenous materials – can they directly use feedstocks that are derived from indigenous materials – does it all have to be done during the printing window or can it the materials be pre-processed? Are there any energy limitations imposed on material processing?

A: See FAQ 3.6 and 3.7

- 3.11. How will aqueous solutions be scored?

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A: Aqueous solutions will be scored by breaking out the water content and scoring the water content with the appropriate 3DP factor (-10). Even if a material is proposed to be produced in-situ, water content must be declared and each substance in the composition should be scored with the appropriate 3DP factor. The final composite 3DP factor will be determined and assigned by the judging panel.

## 4.0 Printing Systems

- 4.1. Are support systems permissible for the dome structure? What are the limitations?

A: Support structures that are fabricated during the head to head competition and/or are part of the printed geometry are permissible, but must be autonomously removed from the structure after printing is complete and prior to testing. In order to facilitate optical scanning for dimensional accuracy, all support material and/or mechanisms shall be removed before testing.

- 4.2. Can a dome support be part of the printing mechanism? If so, how does the rule stating “no pre-fabricated components” apply?

A: The support structure/ mechanism may be integrated as part of the overall printing machine. This is not considered pre-fabricated because the support will not remain in the structure after curing is complete. Placing pre-made objects (manually or autonomously) that become part of the eventual structure would be an example of using pre-fabricated components which are not permitted.

- 4.3. How much time is allotted to print the dome structure in Level 3?

~~A: Teams will be assigned a print start time and a cure end time. This way teams have a little bit of flexibility to optimize cure and print times. However, the logistics of the competition are such that printing will have to stop when the facility closes for the night. Teams should assume a 4 hour print time 8 total hours to get their printer prepped and the printing completed during a given print day, and a minimum of 12 hours for curing.~~

A: The facility hours have been extended for Friday to give the teams the best opportunity to complete their domes. The teams will have access to the arena from 8 AM to 8 PM. The teams will need to remove their cylinder and beam samples (printed on Thursday) from their pallet and prep the pallet and printer/mixes before starting the autonomous print mode in coordination with the judges and staff. The teams will need to exit the arena at 8 PM, so time should be allotted for any required safe shutdown and cleanup of the printer equipment by that time.

- 4.4. Does the dome need to be printed “right side up”

A: Yes, the dome shall be printed with the large diameter ring at the bottom. This would be the method used for a full size structure. For the convenience of the competition, the domes will be printed on a pallet - which will be provided. It will prevent damage as the domes are moved from the team's work area to a central testing location.

- 4.5. Is there a preferred type of printing method?

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A: The intent of the competition is not to prescribe a manufacturing process solution. However, solutions should be developed with space applications in mind. Printing systems should be robust and compatible with reduced gravity environments. The printing system must also be scalable to eventually produce full scale habitats.

A: The selected 3D printing method should be able to support undercuts and overhangs in the printed structure, but manual removal of a support material is not allowed (for example: manually removing a deposited powder bed from around the part). An automated method of support removal is allowed, but the scalability of the overall 3D printing process to large structures for habitats in space and on Earth is a consideration for feasibility. Waste material is undesirable, and large quantities of wasted feedstock are highly discouraged due to the inefficiencies involved. NASA would like to use appropriate 3D additive construction processes on the Moon or Mars, so it is highly encouraged to have traceability to a method that would work in an outer space environment, including a vacuum, reduced gravity, and extreme temperature thermal swings. Any questions related to the feasibility of the selected additive construction process at large scales and in an outer space environment shall be referred to the judges panel for resolution. All decisions made by the judges are final and may not be appealed or contested.

#### 4.6. What is the power source at Level 3?

A: Power will be provided at the competition site. 120V or 240V single phase power or 480V three phase power may be requested by the teams. All power provided will be 60 Hz. As the level 3 competition approaches, the teams will be asked to provide more information on their power requirements within these limitations so the facility can be prepared for competition.

#### 4.7. May an autonomously deployed and removed form be used to print the truncated cone, the ASTM C39 sample, or the ASTM C78 sample?

A: No, autonomous forms may only be used (if desired) to support the construction of the dome at the level 3 competition.

#### 4.8. Is it legal to use or modify an existing 3D printer, or use parts from an existing printer? What percentage of the printer must be manufactured by the team?

A: Yes, teams may reuse any number of components from existing products to construct a unique printing system.

#### 4.9. How will the tolerances provided in the rules be enforced?

A: For tests performed as part of the Level 1 Compression Test and Level 2 Beam Test, the team will be responsible for ensuring compliance with tolerance requirements. If a

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specimen for these tests is printed that is not within tolerance, then a new one should be prepared which meets the criteria. Specimens which do not meet the tolerance specifications will receive a score of zero.

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4.10. The rule book states that "Teams may resupply, or refill, the feedstock into the 3D printer system between specimen productions." Does this mean that you cannot refill while a specimen is being produced?

A. Human intervention to resupply the printer is not allowed during specimen production (specimen being a cone, cylinder, beam, or dome). Automated refill during specimen production is allowed.

4.11. Can time be added to the overall print time allotted?

A. All teams will be allotted the time for printing on each day of the competition. The arena will be open to the competitors at 8:00 am and close at 6:00 pm on Thursday and open at 8:00 am and close at 8:00 pm on Friday. All beams and cylinders will be printed on Thursday, and the domes will be printed on Friday.

4.12. Can we print directly from a printer mounted on a flatbed trailer as opposed to transferring it to a new space to print; do we need to remove the printer and set it up on a given location?

A. Printing from a trailer is allowed, as long as it is safe and stable.

## 5.0 Testing

5.1. Is there a deformation criteria for the specimens?

A: No, just load to failure. This question suggests the intent to build specimens from a high percentage of recycled materials. Refer to the rules for minimum quantities of indigenous materials.

5.2. Can sample be trimmed and capped for cylinder test?

A. Yes, it can be trimmed and/or capped per ASTM C39 specification section 6.2; however, the as-printed dimensions must be documented in the video and be within tolerance before the ends are trimmed.

5.3. Can the cylinder be stored in water during the 48 hour curing time?

A. Although moist curing is referenced in ASTM C39, it will not be an available option for any of the test samples at the head to head competition.

5.4. Can the test specimen be manually constructed from smaller parts or can a team print smaller test specimens (which are allowed in the standard C39 compression tests).

A. No, the intent of the competition is not only to measure compressive or flexural strength but also to demonstrate that the teams can print simples of a certain size and meet specified tolerances autonomously.

5.5. Can the sample sides be smoothed or reworked after printing before the ASTM testing?

A. No, the as-printed dimensions must be documented in the video and be within tolerance (without any manual rework before testing).

5.6. Can we utilize a different material strategy for each structure in Level 3?

A. No. In accordance with Rules 7.3.1 and 7.3.2 each team shall 3D print ASTM C39 compression and ASTM C78 flexural specimens of the elected material to be used in the construction of the dome structure. Only material used to construct the dome shall be used to construct the beam and cylinder.

5.7. Will our team be disqualified if we submit less than 3 specimens for each ASTM C39 compression and ASTM C78 flexural tests?

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- A. No, teams won't be disqualified if they cannot finish printing 3 specimens. Teams will receive zero points for any missing specimens or specimens the judges determine are not suitable to be tested for ASTM C39 compression and ASTM C78 flexural specimen testing.
  
- 5.8. On Day 1, will all three cylinders and all three beams have to be printed within a single pallet? How many palletes will be supplied to the team?
  
- A. All cylinders and beams will be printed within a single pallet. 1 pallet will be supplied to each team.

## 6.0 On-site Competition Arena

6.1. Is a printing surface provided to us such as a palette? If so can the palette be modified or can we add a pallet on top of it?

A. A standard painted steel pallet will be provided to each team for the purpose of providing a surface to print the dome and for moving the printed dome to the structural testing apparatus. The cylinders and beams should be printed on the pallet on Thursday, and the dome should be subsequently printed on the pallet on Friday. The standard pallet is required to facilitate material handling and the insertion of the dome into the test equipment. The steel pallet will be approximately 180 cm x 180 cm x 11.43 cm high. There will be a locating hole in the center of the pallet and additional holes around the perimeter to facilitate tie downs. The teams will be allowed to add a sheet/layer of any material not exceeding 7mm but the matching holes and notches will need to be included in the sheet. While the cylinders and beams will be removed to be placed into a machine for testing, the testing method of the dome will require that the interface sheet remains in place and will also be subject to the compressive load in dome test rig.

6.2. We see that we have available 1-phase 240 V and 3-phase 480 V as available power. How much total power (in watts) will be available from each of these?

A. We intend to provide enough power generation resources to meet the team needs at either single phase 240 V or three phase 480 V. Please let us know how much power you would like to have available.

6.3. What is the height of the high bay, the height and width of the door, and total floor space we have to set up equipment?

A. The doors to the arena are 30 feet wide and 30 feet tall. While the roof is over 40 feet at the peak, we would not expect the printing equipment to exceed 30 feet in height when deployed for printing. We had been planning for nominal 16 by 16 feet workspaces with generous transport aisles in between when planning for 30 teams. We may have some flexibility but we need to consider your request in advance so we can ensure it is within our capabilities.

6.4. Can we attach a robotic arm to the floor in that location?

A. The floor of the arena will be level and highly compacted soil, so nothing can be mounted to the floor; it must be free standing and self-supporting. All systems should demonstrate a factor of safety of 2:1 against overturning.

6.5. What are environmental conditions for material storage, printing and testing?

A. Competition will take place in a sheltered, ventilated but not air conditioned arena with typical August environmental conditions (temperature, humidity, etc.) for Peoria, IL. Materials and equipment shipped by the teams ahead of the competition will also be stored as shipped under the same environmental conditions.